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Movement of Chloropicrin, Vapam, and Methylisothiocyanate in Southern Pine and Douglas Fir Timbers

by

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Movement of Chloropicrin, Vapam, and Methylisothiocyanate in Southern Pine and Douglas Fir Timbers

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SUMMARY

Douglas fir and southern pine timbers, 15.2-cm x 15.2-cm x 4.26-m (6-in x 6-in x 14-ft), were "inoculated" with brown-rot and white-rot fungi as vapor-sensing agents to evaluate the movement and distribution of fungitoxic concentrations of chloropicrin, Vapam, and methylisothiocyanate (MIT) over a 20-week period. Residual fumigant in timbers was determined by a bioassay with Gloeophyllum trabeum.

The fumigants were introduced into 2.54-cm (1-in) holes at midlength in the timbers. Fumigants diffused throughout the cross-sectional area of both pine and Douglas fir. The brown- and white-rot fungi generally showed similar tolerance to the fumigants. Chloropicrin killed most fungal cultures 0.30 m (1 ft) from the treatment center within 1 week after treatment. Vapam and MIT were effective at 0.30 m by 4 weeks. During the 20-week period, kill of cultures at 0.61 m (2 ft) was quite variable by all fumigants, and almost all cultures 1.22 m (4 ft) from the treatment center survived. Bioassay of cores removed from Vapam-treated timbers showed little residual fungistatic effect beyond 0.30 m. Residual fungistatic effect was detected in MIT- and chloropicrin-treated pine and Douglas fir timbers at 0.61 m.

Key words: Fumigation, southern pine, Douglas fir, chloropicrin, Vapam, methylisothiocyanate

INTRODUCTION

Recent studies (Eslyn and Highley, 1985; Highley and Eslyn, 1986) have shown that fumigants can effectively eradicate important brown-rot wood-decay fungi from within large, horizontally oriented pine and Douglas fir timbers, i.e. curbing in waterfront structures. These studies have also provided insight into how far fumigants move horizontally through timbers and how long they remain effective.

Chloropicrin, Diazomet (tetrahydro-3,5-dimethyl-2H-1,3,5-thiadiazine-2-thione) and Vapam (sodium N-methyldithiocarbamate) were the most effective of the fumigants studied.

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Additional information is still needed about the movement, distribution and persistence of fumigants in horizontal timbers exposed out of ground contact. Furthermore, in the previous studies (Eslyn and Highley, 1985; Highley and Eslyn, 1986), only brown-rot fungi were included to test fumigant efficacy. Although not as important as brown-rot fungi in decay of softwood timbers, white-rot fungi also occur in softwood timbers (Zabel et al., 1982) and information is therefore needed on the sensitivity of these fungi to fumigants. Currently, fumigants are generally poured into holes drilled into timbers. Thus their use is limited in many situations because of potential hazards created by spills and leakage that might contaminate people or the environment. Recently, the fumigant, methylisothiocyanate (MIT) became available in pellet form, which is potentially safer than liquid fumigants.

The objectives of this study were to determine the movement, persistence and distribution of chloropicrin, Vapam and MIT in horizontal Douglas fir and pine timbers, and also to test the efficacy of these fumigants in eradication of both brown-rot and white-rot fungi.

MATERIALS AND METHODS

Efficacy of chloropicrin, Vapam, and MIT (Degussa)[2] to move through the timbers was evaluated by the open- and closed-tube bioassays previously described (Scheffer et al., 1982; Highley and Eslyn, 1986).

Test Fungi

Two brown-rot (1 & 2) and three white-rot (3-6) wood decay fungi were used as test organisms: (1) Poria placenta (Fr.) Cke. (MAD-698), (2) Poria carbonica (Overh. (MD-141), (3) Irpex lacteus (Fr.:Fr.) Fr. (HBB-7328-sp.), (4) Bjerkandera adusta (Willd.:Fr.) Karst. (L-15359-sp.), (5) Coriolus versicolor (L.:Fr.) (MAD-697), and (6) Phlebia brevispora Nakas. in Nakasone et Elsyn (HBB-7030-sp.).

Preparation of Inoculum

Screwtop tubes (16- x 125-mm) containing malt agar were inoculated with one of the six test fungi and incubated until growth was well established. A white pine stick (0.47-cm x 0.47-cm x 2.54-cm), previously soaked in distilled water and steam sterilized, was then placed into each tube. The tubes were incubated again until the fungi became established in the sticks.

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal Agencies before they can be recommended.

Preparation of Test Timbers

Sixteen Douglas-fir and 16 southern pine timbers, 15.2-cm x 15.2-cm x 4.26-m (6-in x 6-in x 14-ft), were used. The moisture content of the timbers was approximately 12 percent. Holes for containment of fumigants were 2.54 cm (1 in) in diameter and drilled in clusters about the center of each timber (CL) on the upper surface. The number of treatment holes varied somewhat with the amount of fumigant applied to a given timber. To enhance release of MIT, 20 ml of water was added to treatment holes (Zohora et al., 1985).

On the surface opposite to the fumigation holes, 3 sets of 4 holes each were drilled at distances of 0.30, 0.61, and 1.22 m (1.0, 2.0, and 4.0 ft) from the timber center in both directions. These inoculation holes were either 2.54 cm (1 in) or 7.62 cm (3 in) deep and alternated. The shallow holes permitted evaluation of fumigant movement to the outer area of timbers and the deep holes movement to the interior. A screwtop test tube cap with a hole drilled in the center was glued into each of the inoculation holes. Each of the four holes in one set, i.e. at 0.30, 0.61 and 1.22 m from midcenter, were set up to receive the same fungus. The three sets of holes to the left of timber midcenter received a different fungus than the holes to the right of midcenter. For example, at 0.30, 0.61, and 1.22 m to the left of midcenter, the holes were inoculated with Poria placenta, and the holes to the right of midcenter were inoculated with Poria carbonica.

Exposure of Timbers

The timbers were exposed at the Valley View Exposure Site near Madison, Wisconsin, on racks to elevate them above ground. Timbers were placed with screwtop test tubes facing down to protect the cultures from the sun.

Inspections

Screwtop test tubes with fungal inoculum were removed from each timber at 1, 4, 8, 12, and 20 weeks and replaced with fresh test tube cultures. The removed test tubes were transferred back to the laboratory where the decayed wood stick was transplanted to a fresh tube of malt agar. These tubes were incubated at 27°C (80°F) to determine whether the test fungi remained viable or had been killed, presumably by the fumigant. Controls (test tubes in nonfumigated timbers) were all replaced at each inspection to ensure that each of the six test fungi remained viable during their incubation in the field.

Increment core samples were removed from timbers at 0.30, 0.61, and 1.22 m from timber center to evaluate deposition of fumigants in the wood. The cores were placed immediately into screwtop tubes, the caps tightened, and the tubes transferred back to the laboratory. The cores were sterilized in the tubes and transplanted to screwtop tubes of malt agar inoculated with Gloeophyllum trabeum. The caps were tightened and the tubes incubated at 27°C (80°F) to determine inhibition of growth by the cores.

RESULTS AND DISCUSSION

The efficacy of the fumigants in killing important brown-rot and white-rot fungi implanted into Douglas fir and southern pine timbers through 20 weeks of exposure is given in Tables 1-4. All cultures implanted in the control timbers survived the incubation periods and are therefore not included in the tables.

There was little difference between kill of the cultures implanted into the wood in 2.54-cm or 7.62-cm inoculation holes. Thus, all of the fumigants were able to diffuse throughout the cross-sectional area of both pine and Douglas fir. Generally the brown-rot and white-rot fungi showed similar sensitivity to the fumigants. An exception was Irpex lacteus, which appeared to be tolerant of chloropicrin when implanted into southern pine but was controlled in Douglas fir. Evidently higher concentrations of chloropicrin reached Irpex lacteus in Douglas fir than in the pine.

Chloropicrin killed most of the cultures in both Douglas fir and pine at 0.30 m from the treatment center (CL) within 1 week after treatment. In timbers that received Vapam and MIT, most cultures died at 0.30 m from CL by 4 weeks. During the 20-week period, kill of cultures implanted 0.61 m from CL was quite variable among all the fumigants, and cultures implanted 1.22 m from CL were virtually unaffected.

The fumigants were more effective at 0.61 m from CL in Douglas fir than in pine. In most instances, less than 50% of the cultures in the pine timbers were killed at 0.61 m from CL; Vapam was the least effective. MIT was the most effective fumigant in Douglas fir at 0.61 m from CL, killing 83.3% of the brown-rot cultures and 53.5% of the white-rot cultures (Tables 1 and 3).

In Douglas fir as well as pine, Vapam was the most ineffective fumigant at 0.61 m from CL. The ineffectiveness of the Vapam and chloropicrin at 0.61 m from CL in pine agrees with earlier results obtained with pine timbers exposed in Gulfport, Mississippi (Highley and Eslyn, 1986).

In a previous study (Eslyn and Highley, 1985), Vapam killed most cultures of brown-rot fungi implanted in creosoted Douglas fir timbers 0.61 m from CL. It is difficult to speculate why longitudinal movement in the untreated Douglas fir timbers in the present study was not as great because a number of factors can affect fumigant movement in wood, such as grain direction and checks (Cooper et al., 1974). Pressure treatment may also affect efficacy because the preservative-treated shell can retard escape of fumigant from the wood and thus allow greater longitudinal movement.

Bioassay of increment cores taken from the fumigated timbers at 0.30, 0.61, and 1.22 m from the fumigation holes is given in Table 5. Residual fungistatic effect in wood was similar to that indicated by killing of implanted fungi by vapors from the fumigants. Little fungistatic effect beyond 0.30 m was detected in timbers fumigated with Vapam. By 20 weeks, residual fungistatic effect was detected in both pine and Douglas fir timbers at 0.61 m.

Efficacy of fumigants sometimes varied between timbers. For example, chloropicrin killed virtually all cultures implanted in one Douglas fir timber 0.30 m from CL but none of the cultures implanted in 2.54-cm holes 0.30 m from CL in another Douglas fir timber. We have observed similar variation in horizontal timbers in other studies (Eslyn and Highley, 1985; Highley and Eslyn, 1986). Scheffer and Graham (1975) also found variation of fumigant efficacy between different Douglas fir poles. Thus those planning to use fumigants in control of wood-decay fungi should be aware of the inherent variability that may affect efficacy of treatment.

CAUTION

Vapam and chloropicrin are registered with the U.S. Environmental Protection Agency, and are used extensively for controlling interior decay in poles. However, the fumigants used in these field trials are hazardous and extreme care must be employed, particularly where the chemicals might spill or leak into the surrounding environment. Furthermore, fumigants should not be used on timbers located within structures or poorly ventilated areas.

Table 1 Viability of brown-rot fungus cultures inoculated into Douglas fir timbers at different depths and distances from fumigation sites

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3,4]									
				1 week		4 week		8 week		12 week		20 week	
				Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc
Vapam	0.30	1	2.5	+ +	+ +	+ -	+ -	+ -	- -	- -	- -	- -	- -
			7.6	+ +	+ +	+ -	- -	- -	- -	- -	- -	- -	- -
470 ml		2	2.5	+ +		+ -		- -		- -		- -	
			7.6	+ +		- -		- -		- -		- -	
	.61	1	2.5	+ +	- +	+ +	- +	+ +	+ +	+ +	+ +	+ +	+ -
			7.6	+ +	- +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	- -
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		- -	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	
Methyliso-thiocyanate	.30	1	2.5	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -
			7.6	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -
120 g		2	2.5	- +		- -		- -		- -		- -	
			7.6	- +		- -		- -		- -		- -	
	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	- -	+ +	- -	- +
			7.6	+ +	+ +	+ +	+ -	+ -	+ +	- -	- -	- -	+ -
		2	2.5	+ +		+ +		+ +		- +		- -	
			7.6	+ +		+ +		+ -		- +		- -	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ -	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	

Table 1 Viability of brown-rot fungus cultures inoculated into Douglas-fir timbers at different depths and distances from fumigation sites (cont.)

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3,4]									
				1 week		4 week		8 week		12 week		20 week	
				Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc
Chloropicrin	0.30	1	2.5	- +	- -	- +	- -	- +	- -	+ -	- -	+ -	- -
			7.6	- -	- +	- -	- -	- -	- -	- -	- -	- -	- -
250 ml		2	2.5	- -		- -		- -		- -		- -	
			7.6	- +		- -		- +		- -		- -	
	.61	1	2.5	+ +	+ +	+ +	- -	+ -	- -	+ +	- -	+ -	- -
			7.6	+ +	+ +	+ -	+ +	- -	+ +	- -	- +	+ -	- +
		2	2.5	+ +		- -		- -		- -		- -	
			7.6	+ +		+ +		+ +		- +		- +	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	

[1]One or two timber replications
[2]Inoculation hole depth
[3]Viability: - = no growth, culture presumed dead; + = positive growth
[4]Culture: Pp = Poria placenta; Pc = Poria carbonica

Table 2 Viability of brown-rot fungus cultures inoculated into southern pine timbers at different depths and distances from fumigation sites

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3,4]									
				1 week		4 week		8 week		12 week		20 week	
				Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc
Vapam	0.30	1	2.5	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -
			7.6	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -
470 ml		2	2.5	+ +		+ -		- -		+ -		+ -	
			7.6	+ +		- -		- -		- -		- -	
	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		- +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ -		+ -	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	
Methyliso-thiocyanate 120 g	.30	1	2.5	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -
			7.6	+ +	+ +	- +	- -	- -	- -	- -	- -	- -	- -
		2	2.5	+ +		- -		- -		- -		- -	
			7.6	+ +		- -		- -		- -		- -	
	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +
			7.6	+ +	+ +	+ +	+ -	+ +	+ +	+ +	+ +	+ +	- +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	
	1.22	1	2.5	+ -	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	

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Table 2 Viability of brown-rot fungus cultures inoculated into southern pine timbers at different depths and distances from fumigation sites (cont.)

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3,4]									
				1 week		4 week		8 week		12 week		20 week	
				Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc	Pp	Pc
Chloropicrin	0.30	1	2.5	- -	- -	- -	- -	+ -	- -	+ -	- -	+ -	- -
			7.6	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
250 ml		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ -		- -		- -		- -		- -	
	.61	1	2.5	+ +	+ +	+ +	+ -	- +	+ -	+ +	+ -	+ +	+ -
			7.6	+ +	+ +	- -	- -	- +	- -	- -	- -	- -	- -
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +		+ +		+ +		+ +		+ +	
			7.6	+ +		+ +		+ +		+ +		+ +	

[1]One or two timber replications
[2]Inoculation hole depth
[3]Viability: - = no growth, culture presumed dead; + = positive growth
[4]Culture: Pp = Poria placenta; Pc = Poria carbonica

Table 3 Viability of white-rot fungus cultures inoculated into Douglas fir timbers at different depths and distances from fumigation sites

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3]																			
				1 week				4 week				8 week				12 week				20 week			
				Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb
Vapam	0.30	1	2.5	+ +	+ +	- +	+ +	- -	- -	- +	- +	- -	- -	- -	- +	- -	- -	- -	+ +	- -	- -	- -	+ +
			7.6	+ +	+ +	+ +	+ +	- -	- +	- +	+ +	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -
470 ml		2	2.5	+ +	+ +	+ +		+ -	- -	+ -		- -	- -	+ -		- -	- -	+ -		- -	- -	+ -	
			7.6	+ +	+ +	- +		- -	- -	- -		- -	- -	- -		- -	- -	- -		- -	- -	- -	
	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +	+ +	+ +	- +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	+ +	+ +	+ +	+ -	+ -	+ +	- +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ -	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ -	+ -	+ +		+ -	- -	+ +	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
Methyliso-thiocyanate	.30	1	2.5	+ +	+ +	+ +	+ +	+ -	- -	- +	- -	- -	- -	- -	- -	+ -	- -	- -	- -	+ -	- -	- -	- -	- -
			7.6	+ +	+ +	+ +	+ +	- -	- +	- +	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
		2	2.5	+ +	+ -	+ +		+ -	+ -	- -		- -	+ -	- -		- -	- -	- -		- -	+ -	- -	
			7.6	+ +	+ -	+ +		- -	- -	- -		- -	- -	- -		- -	- -	- -		- -	- -	- -	
120 g	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +	+ +	- -	- +	- -	+ +	- -
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	+ +	+ +	- +	- +	- +	+ -	- +
		2	2.5	+ +	+ +	+ +		+ +	- +	+ +		+ +	- +	+ -		+ +	+ -	+ -		+ +	+ -	+ -	
			7.6	+ +	+ +	- +		+ +	+ +	+ +		+ +	+ +	- -		+ -	- -	- -		+ -	- +	- -	
	1.22	1	2.5	+ +	+ +	+ +	- +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	

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Table 3 Viability of white-rot fungus cultures inoculated into Douglas fir timbers at different depths and distances from fumigation sites (cont.)

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3]																			
				1 week				4 week				8 week				12 week				20 week			
				Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb
Chloropicrin	0.30	1	2.5	- -	+ -	- -	+ +	- -	- -	- -	- +	- -	- -	- -	- +	- -	- -	- -	+ +	- -	- -	- -	- +
			7.6	- -	+ -	- -	+ +	- -	- -	- -	+ +	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -	- -	- +
		2	2.5	- +	+ -	- -		- -	- -	- -		- -	- -	- -		- -	- -	- -		- -	- -	- -	
			7.6	- +	+ -	- +		- -	- -	- -		- +	- -	- -		- -	- -	- -		- +	- -	- -	
250 ml	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	- +	+ +	+ +	+ +	- +	- +	+ +	- +	- -	- +	+ +	+ +	- -	- +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	- +	+ +	+ +	- +	- +	+ +	+ +	- -	- +	+ -	+ -	- +	- +	- +
		2	2.5	+ +	+ +	+ +		+ +	+ +	- +		+ +	+ +	- +		+ +	+ +	- -		+ +	+ +	- -	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ -	+ +		+ -	- -	- +		+ +	- -	- +	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	

[1]One or two timber replications

[2]Inoculation hole depth

[3]Viability: - = no growth, culture presumed dead; + = positive growth. Culture: Il = Irpex lacteus; Ba = Bjerkandera adusta; Cv = Coriolus versicolor; Pb = Phlebia brevispora

Table 4 Viability of white-rot fungus cultures inoculated into southern pine timbers at different depths and distances from fumigation sites

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3]																			
				1 week				4 week				8 week				12 week				20 week			
				Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb
Vapam	0.30	1	2.5	- +	+ +	+ +	+ +	- -	- -	- -	+ -	+ -	- -	- -	+ -	- -	- -	- -	- -	- -	- -	- -	+ -
			7.6	- +	+ +	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
470 ml		2	2.5	+ +	+ +	+ +		- -	- -	+ -		- -	- -	- -		- -	+ -	+ -		- -	- -	- -	
			7.6	- +	+ +	+ +		- -	- +	- -		- -	- +	- -		- -	- +	- -		- -	- -	- -	
	.61	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	- +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		- +	+ +	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ -	+ -	+ +		+ -	+ +	+ +	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
Methyliso-thiocyanate	.30	1	2.5	+ +	+ +	+ +	+ +	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
			7.6	+ +	+ +	+ +	+ +	- +	- -	- -	- -	- -	- -	- -	- +	- -	- -	- -	- -	- -	- -	- -	- -	- -
		2	2.5	+ +	+ +	+ +		- -	+ -	- -		- -	- -	- -		- -	- -	- -		- -	- -	+ -	
			7.6	+ +	+ +	+ +		- -	- -	- -		- -	- -	- -		- -	- -	- -		- -	- -	- -	
120 g	.61	1	2.5	+ +	+ +	- +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +	- +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ -	+ -	+ +	+ +	- +	- -	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
			7.6	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ -	+ -		+ +	+ -	+ -	
	1.22	1	2.5	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	- +	+ +	+ +	+ +	+ +	+ +
			7.6	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +	+ +
		2	2.5	+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ +	+ +	
			7.6	+ +	+ +	- +		+ +	+ +	+ +		+ +	+ +	+ +		+ +	+ -	+ +		+ +	+ -	+ +	

Table 4 Viability of white-rot fungus cultures inoculated into southern pine timbers at different depths and distances from fumigation sites (cont.)

Fumigant	Distance (m)	Timber replications[1]	Hole depth[2] (cm)	Time of assay following fumigation and viability of cultures[3]																			
				1 week				4 week				8 week				12 week				20 week			
				Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb	Il	Ba	Cv	Pb
Chloropicrin	0.30	1	2.5	+	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-
			7.6	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	+	+	-	-
250 ml		2	2.5	+	+	-	-	-	-	+	+	-	-	-	-	+	+	-	-	-	-	+	+	-	-	-	-	+	+	-	-
			7.6	+	+	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-
	.61	1	2.5	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+	+	+	+	-	-	+	-	+	+	-	-
			7.6	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	-	-	+	-	-	+	-	-	+	+	-	-
		2	2.5	+	+	+	-	+	+	+	+	-	+	+	+	-	+	-	-	+	+	+	-	-	-	+	+	-	-	-	-
			7.6	+	+	+	+	+	+	-	+	+	+	+	+	-	+	-	-	-	-	-	-	-	-	+	+	-	-	-	-
	1.22	1	2.5	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
			7.6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
		2	2.5	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		
			7.6	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		

[1]One or two timber replications

[2]Inoculation hole depth

[3]Viability: - = no growth, culture presumed dead; + = positive growth. Culture: Il = Irpex lacteus; Ba = Bjerkandera adusta Cv = Coriolus versicolor; Pb = Phlebia brevispora

Table 5 Fungistatic[1,2] effect of cores extracted from Douglas fir and southern pine timbers after fumigation with chloropicrin, Vapam, and methylisothiocyanate (MIT)

Treatment	Distance from treatment	Time lapse since treatment (weeks)									
		1		4		8		12		20	
		Pine	Fir	Pine	Fir	Pine	Fir	Pine	Fir	Pine	Fir
	m										
Vapam (470 ml)	0.30	3	0	3	3	3	3	3	3	3	3
	.61	0	0	0	0	1	0	1	2	1	2
	1.22	0	0	0	0	0	0	0	0	0	0
	1.80	0	0	0	0	0	0	0	0	0	0
MIT (120 g)	.30	1	2	3	3	3	3	3	3	3	3
	.61	0	0	0	3	0	3	0	3	2	2
	1.22	0	0	0	0	0	0	0	0	0	2
	1.80	0	0	0	0	0	0	0	0	0	0
Chloropicrin (250 ml)	.30	3	3	3	3	3	3	3	3	3	3
	.61	0	0	0	2	2	3	2	3	3	3
	1.22	0	0	0	0	0	3	0	0	0	0
	1.80	0	0	0	0	0	0	0	0	0	0

[1]0 = No inhibition
1 = Slight inhibition
2 = Severe retardation of growth
3 = No growth

[2]Gloeophyllum trabeum assay fungus

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